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(54) Laser diode pumped solid state laser with miniaturized quick disconnect laser head

(57) A compact laser head (10) for a solid state laser has a miniaturized laser rod (28) and output coupling mirror (16) which form a miniataurized laser cavity. A miniaturized frequency doubler crystal (46) placed in the cavity provides frequency doubled output. The laser head is connected by an optical fibre (42) to a separate power supply which contains a laser diode pumping source. A quick disconnect connector (40) enables the optical fibre to be easily connected to the laser head. Pumping radiation is transmitted through the optical fibre to longitudinally end pump the laser rod using fibre optics coupling imagery. The fibre is aligned with the rod by the connector and the pumping radiation is imaged into the rod by a focussing sphere (32). The pumping volume is matched to the lasing volume which is determined by the cavity geometry. The quick disconnect laser head allows interchange of different heads with different output characteristics while using a single power supply.

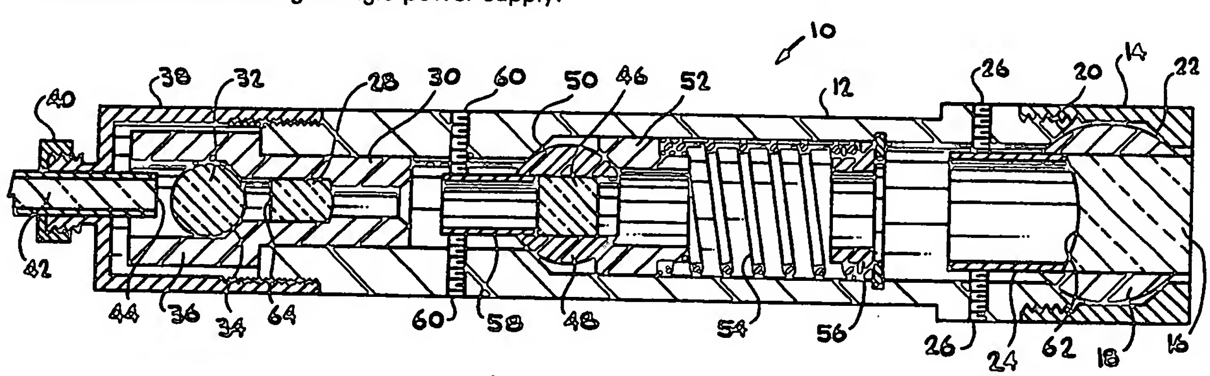

FIG. 1

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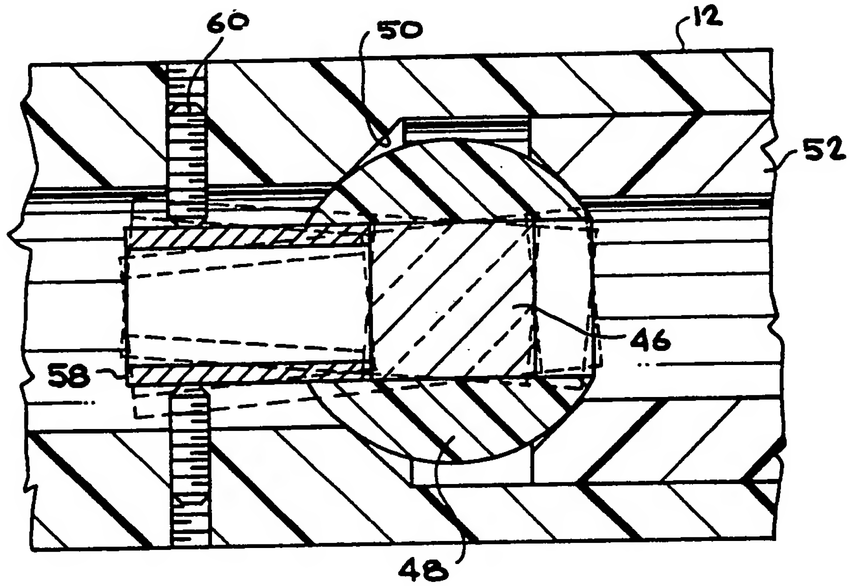

FIG. 2

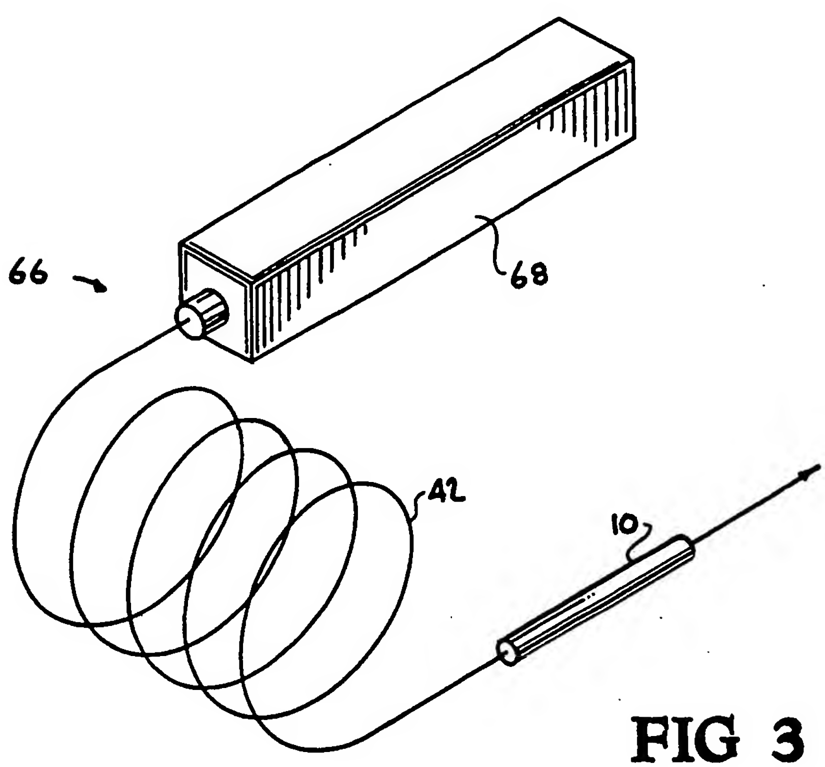

FIG 3

which includes a laser diode pumping source. Each head can be designed to provide particular output characteristics. Thus a very versatile system is provided in which only the laser heads are interchanged. The small size of the laser head and the ability to move the laser head a distance from the power supply are highly advantageous for a variety of applications. Furthermore, the laser diode can be replaced when necesary without any adjustment or realignment of the laser head components.

In order that the invntion may be readily understood, an embodiment thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a sectional view of a quick disconnect miniaturized laser head embodying the invention;

Figure 2 is a sectional view of a ball and tube mount holding a doubler crystal in the laser head; and

Figure 3 is a perspective view of a laser system showing the laser head connected to a power supply through an optical fibre.

A quick disconnect compact solid state laser head 1 0 in accordance with the invention is shown in Figure 1. The laser head 10 has a hollow housing 12 which is preferably substantially cylindrical or tubular and typically made of stainless steel. At one end of housing 12 is end cap 14, typically made of plastic, e.g. Teflon (RTM) impregnated Delrin (RTM), which screws onto or is otherwise attached to housing 12. A mirror 16 is mounted at the end of housing 12 and inside end cap 14. Mirror 16 preferably has a concave inner surface and substantially flat outer surface. Mirror 16 forms a part of the laser optical cavity and is the output coupler for the laser cavity. Mirror 16 is held in a ball mount 18 which is rotatably mounted in end cap 14 between bevelled edge 20 of housing 12 and bevelled edge 22 of end cap 14. Ball mount 18 has a hollow tube 24 extending therefrom into the interior of housing 12. Set screws 26 extend through housing 12 and contact tube 24 so that the angular position of ball mount 18 can be adjusted; there are typically three of four set screws 26 spaced around the circumference of the housing.

Near the opposite end of housing 12 is mounted a solid state laser rod 28 which is held in a holder or mount 30 which fits within the housing 12; the rod 28 may be held in place by a set screw (not shown) which also stresses the rod to polarize the output. Alternatively, laser rod 28 can be mounted in a ball mount if desirable to adjust its angular orientation. Mount 30 also holds a spherical lens or focussing sphere 32 in a spaced relationship to laser rod 28; the lens 32 may be epoxied in place. Spherical lens 32 is mounted against bevelled edge 34 in end portion 36 of mount 30; end portion 36 is wider than the portion of mount 30 which holds laser rod 28. An end cap 38 is placed at the end of housing 12 and contains the end porti n 36 of mount 30. End cap 38 is typically made of Teflon impregnated Delrin. End cap 38 also cantains coupling means 40 which allow an optical fibre 42 to be connected to laser head 10. Coupling means 40 is preferably a standard fibre optics connector, either bayonet type or SMA (screw-on) type, e.g. Amphenol 905 and 906 series connectors from Allied Corp., or any other coupling means which provides fibre alignment and quick connect/disconnect. Coupling means 40 holds optical fibre 42 so that its end 44 is in close proximity to spherical lens 32. Laser rod 28, spherical lens 32 and the end 44 of optical fibre 42 are positioned so that the output of optical fibre 42 is imaged into laser rod 28 to provide efficient longitudinal end pumping of laser rod 28. Coupling means 40 provides proper alignment of fibre 42 which is reliable each time the fibre is connected to the laser head.

A frequency doubler crystal 46 may also be mounted in the housing 12 in order to produce a frequency doubled output. Doubler crystal 46 is mounted in a ball mount 48 which is held against bevelled edge 50 on the interior of housing 12 by ball retainer ring 52 which is spring loaded by spring 54 which is held by spring retainer 56 which is mounted in housing 12. Ball mount 48 has a hollow tube 58 extending therefrom longitudinally in housing 12. Set screws 60 extend through housing 12 and contact tube 58 so that the angular position of ball mount 48 can be adjusted; typically three or four set screws 60 are used.

In accordance with the principles described in U.K. Patent Application No. 2175127A and the packaging techniques of the present invention a very short optical cavity is produced. The optical cavity is defined by surface 62 of mirror 16 and surface 64 of laser rod 28. Surface 64 is transmissive to pumping radiation but reflective to the lasing output of laser rod 28 and the frequency doubled radiation in cases where the doubler crystal 48 is used. By proper selection of the curvature of the optical surfaces and the distances between the optical surfaces, the beam prof ile within the cavity is controlled. In particular a beam waist is formed within the cavity which provides the optimal position for placement of the doubler crystal 46. Also by mode matching the beam profile to the cavity dimensions single transverse mode operation, e.g., TEM_{00} mode, can be achieved.

The optical elements 16, 28, 46 are provided in housing 12 at th appropriate positions according to a particular cavity design. The elements are centered along the bore of housing 12. To perform the initial alignment of optical elements 16 and 46, ball mounts 18 and 48, r sp ctively, ar rotated. The angular adjustment of doubler crystal 46 in ball mount

wherein the laser rod is a Nd:YAG crystal.

4. A laser head according to any one of claims 1 to 3, wherein the miniaturized output coupling mirror is mounted in a ball mount which is rotatably mounted in the housing.

5. A laser head according to claim 4, wherein the ball mount for the output mirror includes a projecting tube extending longitudinally in the housing and further including position adjustment means mounted in the housing and contacting the projecting tube for rotating the ball mount.

6. A laser head according to any one of claims 1 to 5, further including a miniaturized frequency doubler crystal mounted in the housing in the miniaturized laser cavity.

7. A laser head according to claim 6, wherein the miniaturized frequency doubler crystal is mounted in a ball mount which is rotatably mounted in the housing.

8. A laser head according to claim 7, wherein the ball mount for the frequency doubler crystal includes a projecting tube extending longitudinally in the housing and further including position adjustment means mounted in the housing and contacting the projecting tube for rotating the ball mount.

9. A laser head according to any one of claims 6 to 8, wherein the laser cavity produces a beam profile having a beam waist and the frequency doubler crystal is mounted at the beam waist.

10. A laser head according to any preceding claim, wherein the imaging means is a focussing sphere.

11. A laser head according to any preceding claim wherein the laser cavity is mode matched to the lasing volume of the laser rod to produce substantially TEM_{00} mode output.

12. A laser head according to any preceding claim wherein the quick disconnect means is a bayonet type fibre optics connector.

13. A laser head according to any one of claims 1 to 1 1, wherein the quick disconnect means is a screw-on type fibre optics connector.

14. A compact laser head, comprising: a compact hollow housing; a first end cap attached to one end of the housing; a first ball mount rotatably mounted between a first bevelled edge on the surface of the housing and the first end cap; a miniaturized output coupling mirror mounted in the first ball mount; the first ball mount having a tube extending therefrom longitudinally into the housing; first position adjustment means extending through the housing and contacting the tube of the first ball mount for rotating the first ball mount; a holder mounted in the other end of the housing; a miniaturized solid state laser rod mount d in the holder; the laser rod and output coupling mirror forming a miniaturized laser cavity; imaging means mounted in the holder in a spaced relationship to the laser rod; a second end cap attached to the housing and surrounding the holder; quick disconnect means extending from the second end cap for connecting an optical fibre to the housing so that the imaging means images the output of the optical fibre into the laser rod to longitudinally end pump the laser rod.

15. The compact laser head of claim 14, further comprising: a second ball mount rotatably mounted against a second bevelled edge on the inside of the housing; a miniaturized frequency doubler crystal mounted in the second ball mount; a retaining ring contacting the second ball mount; a spring contacting the retaining ring; a spring holder fixedly mounted in the housing for compressing the spring against the retaining ring to hold the second ball mount against the second bevelled edge; the second ball mount having a tube extending therefrom longitudinally into the housing; second position adjustment means extending through the housing and contacting the tube of the second ball mount for retaining the second ball mount.

16. A solid state laser system, comprising: a compact laser head according to any preceding claim; a laser power supply including a laser diode pumping source; an optical fibre connected from the power supply to the laser head to transmit pumping radiation from the pumping source to the laser head.

17. A compact laser head substantially as hereinbefore described with reference to the accompanying drawings.

18. A solid state laser system substantially as hereinbefore described with reference to the accompanying drawings.

19. Any novel features or combination of features described herein.

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